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Silviculture Report

Lover’s Canyon Project

Scott River Ranger District, Klamath National Forest
Siskiyou County, California

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Introduction

The purpose of this initiative is to manage the Lover's Canyon landscape so that individual landscape elements and patterns are resilient to ecological processes occurring on the landscape scale, including wildfire, while managing for certain habitat characteristics, such as those for the Northern Spotted Owl, visual objectives, and sustainable resource outputs. This action is needed because a resilient landscape is a diverse one, where no single element being removed from the ecosystem will affect the entire system. A measure of diversity on a landscape level is the stand structural class expressed as a percentage of the landscape it takes up. Much of the project area is in the small conifer structural class. The existing condition was determined using Region 5 remote sensing data.

Through collaboration with the Lower Scott River Fire Safe Council, a second purpose was identified. That is to implement objectives outlined in the Lower Scott River Community Wildfire Protection Plan.

The Canyon Ecosystem Analysis was prepared to provide a means by which the landscape can be understood as an ecological system, and to use this knowledge to help shape the landscape patterns created through National Forest land management activities. The document describes desired conditions for stand structural classes, defined by the stand quadratic mean diameter (QMD), in terms of percentage of area within the landscape and is depicted in below. Basically, the QMD is the diameter at breast height (dbh) of the tree of average basal area in a stand. The range of desired conditions, along with individual element descriptions; are designed to be consistent with landscape scale processes; provide a variety of habitat values; provide a variety of opportunities for human uses; as well as sustainable and predictable levels of resource outputs (Canyon Ecosystem Analysis, 1994). This action responds to the goals and objectives outlined in the Klamath National Forest Land and Resource Management Plan (Forest Plan), and helps move the project area towards desired conditions described in that plan (Forest Plan, as amended, 1995).

Table 1. Desired vs. Existing Condition of Structural Class

Structural Class	Desired Condition Range	Existing Condition
Seedling/Sapling (0-5.9" dbh)	5-15%	6%
Poles (6"-10.9" dbh)	10-20%	7%
Small Conifer (11"-24.9"dbh)	15-35%	46%
Medium/Large Conifer ($\geq$25" dbh)	40-60%	38%

This analysis will address the issues and opportunities surrounding the promotion of more vigorous, insect and disease resistant stands and the protection of resources from the unacceptable risk of stand replacing wildfire in the Lower Canyon Creek, Upper Canyon Creek, Boulder Creek, Isinglass Creek, Deep Creek, and South Fork Kelsey Creek 7th field watersheds on the Scott River Ranger District of the Klamath National Forest. The project is located from the Marble Mountain Wilderness boundary to the banks of the Scott River on generally north and west facing slopes. Over ninety percent of the project area is in federal ownership with the remainder a mix of industrial forestland and individual, small, privately owned tracts. The stands in this project area have been designated as General Forest MA-17, Partial Retention Visual Quality Objective MA-15, Designated and Recommended Recreational River MA-13, Retention Visual Quality Objective MA-11 and Riparian Reserves MA-10 (Forest Plan 1995). Management direction emphasizes: Maintenance of stand health, as well as resilience to wildland fire, insects and disease; emulating ecological processes and stand and landscape patterns where possible; providing an attractive, forest landscape where management activities remain visually subordinate to the character of the landscape; being consistent with the aquatic conservation strategy goals.

Methodology

Stand dynamics have been modeled using the Forest Vegetation Simulator (FVS). Field data were collected from a representative sample of stands in the various categories during the summer/fall of 2012 and spring of 2013. The modeled results from FVS are not intended to be absolute values; rather they display relative trends in stand development for each of the defined categories. It is also important to remember that the models are run for the average treatment across the stand category. While the models are developed from actual stand category data and would reflect variation within the category they do not necessarily display the within stand variability. For example, the culturing of large trees will require wider spacing around selected trees (thirty-five feet and more) compared with the more common closer spacing (twenty five to thirty feet). The model only addresses the average thinning accomplished in the stand. Also FVS does not consider unthinned areas within a stand. These no cut areas would have slower growth, higher mortality and an increasing build-up of fuels. There would be an effect on vegetation surrounding the uncut patch in the form of reduced growth and increased fire hazard.

Inventory plots were located (2012 and 2013) in most of the stands to determine current stand attributes including the site class, canopy cover, basal area, trees per acre, snag densities, fuel loading, and stand density. These data were run through the Forest Vegetation Simulator (FVS) to model the future growth of stands and the predicted mortality in the event of a fire. This was compared to the stand objectives and treatments designed to take the stands from their current state to where they could provide desired stand health objectives and become more resilient to fire. Stand treatments were developed and assessed with the Forest Vegetation Simulator to test the effect of the treatments on stand development and fire resistance (Keyes 2002).

Treatments will be designed to reduce extreme fire behavior potential and stand density in order to promote growth and development of stands that are healthier, structurally diverse and more fire resilient. Stands would be thinned and trees would be removed from the treated stands as biomass or saw logs. Trees would be harvested using cable and tractor harvesting systems. Hardwoods, in general, would be cultured to maintain them as an integral part of the stands.

Due to species composition and average stand age the project stands have been divided into two major categories. The categories are natural small conifer stands and conifer plantations.

Field Investigation: All stands planned for treatment received an on-site field review by a certified silviculturist. Stand diagnosis and site specific prescriptions were then developed.

<u>Analysis and Report Time:</u> A total of sixteen days were spent in the field collecting vegetation data, formulating stand diagnosis, and writing preliminary silvicultural prescriptions by a certified silviculturist. A field crew of four people spent 10 days collecting vegetation and fuels data to be used in the forest vegetation simulator to model existing and projected stand structures. Approximately twenty five days were spent analyzing data, writing this report, completing a Stand Record Card for each stand, providing input into the NEPA process, and attending interdisciplinary meetings.

Analysis Indicators

- **Provide sustainable resource outputs in the Project Area**: The measures for this analysis indicator will show that the need to provide sustainable and predictable levels of resource outputs is being met.
- **Trend towards desired conditions for conifer stand structure**: The measures for this analysis indicator will show that the need to meet the desired conditions of structural classes in order to shape a diverse and resilient landscape is being met.

Measures

Stand Density Index: Stand density affects stand health and the ability of trees to respond to disturbance mechanisms. Stand Density Index (SDI) is a relative measure of stocking levels expressed as a number of 10-inch diameter trees per acre. High stand density, such as what is found in the project area, leads to competition for limited resources needed for growth and survival. Competition in turn, leads to reduced growth and vigor, increased susceptibility to insects and disease, and to eventual mortality. Weakened trees are more likely to succumb to the effects of disturbance mechanisms such as disease, insects, and fire.

Reineke first introduced SDI as a measure of site occupancy in 1933. He found that SDI could be consistently applied to calculate a maximum density expected for a given average stand diameter. SDI has an advantage over basal area because it is not significantly affected by age and site quality. Maximum SDI values have been developed for a variety of species including white fir, Douglas-fir and ponderosa pine. The maximum SDI value for each species is 759, 600, and 436 respectively.

In order to minimize self-thinning and associated fuels build-up, and to promote growth, stands should be below 55% of maximum SDI (Reineke 1933). A zone of imminent mortality, or where self-thinning begins to occur, is reached at 55% of maximum SDI (Reineke 1933). This would equate to SDI values of 418 for white fir, 330 for Douglas-fir and 241 for ponderosa pine. Different tree species will be able to grow and prosper at different stand densities as previously listed. For example, in a mixed conifer stand with an SDI of 500 one could expect to find that most of the ponderosa pine have died, the Douglas-fir struggling to maintain itself and the white fir still growing but at a slow rate.

Table 2. Detailed Explanation of SDI Classes

% Maximum SDI	Competitive Interactions
0-24% Low Density	Less than full site occupancy, maximum understory forage production. No competition between trees, little crown differentiation. Maximum individual tree diameter growth. Minimum whole stand volume growth.

25-34% Moderate Density	Less than full site occupancy, intermediate forage production. Onset of competition among tree, onset of crown differentiation. Intermediate individual tree diameter growth. Intermediate whole stand volume growth.
35-55% High Density	Full site occupancy, minimum forage production. Active competition among trees, active crown differentiation. Declining individual tree diameter growth. Maximum whole stand volume growth. Upper range of zone marks the threshold for the onset of density-related mortality.
56+% Extremely high density	Full site occupancy, minimum to no forage production. Severe competition among trees, active competition-induced mortality. Minimum individual tree diameter and growth, stagnation. Declining whole stand volume growth due to mortality.

Table 3 Numeric Values of SDI Classes by Species

SDI Class	PP/SP/MC SDI Range	DF	WF	IC	RF
Low Density (0-24% of SDImax)	0-104	0-144	0-182	0-136	0-192
Moderate Density (25-34% of SDImax)	105-148	145-204	183-258	137-194	193-272
High Density (35-55% of SDImax)	149-240	205-330	259-417	195-314	273-440
Extremely High Density (56+% of SDImax)	241 +	331 +	418 +	315 +	441 +
SDImax	436	600	759	570	800

Basal Area: The cross sectional area of the bole of a tree at breast height (4.5 feet). This is measure of the amount of space taken up by a tree or trees and usually reported on a per acres basis.

Quadratic Mean Diameter: This is the diameter of a tree of average basal area of the stand. This is similar, but not equal to the average tree diameter. The quadratic mean is generally used instead of the arithmetic mean in forest measurements as it is directly related the stand basal area and volume, and is used in this case as it was a measurement presented in the Canyon Creek Ecosystem Analysis. This number will be compared between alternatives at current stand conditions and thirty years out.

Stand Structure: Is represented by (1) the average size of trees, and (2) the number or percentage of "large" trees in a stand. To illustrate the change in stand structure with or without treatment, the analysis of the average size of trees uses Quadratic Mean Diameter, the diameter of the tree of average basal area in the stand. Shown as a percent of seedling/sapling (0- to 5.9-inch dbh); poles (6- to 10.9-inch dbh); small conifer (11 – to 24.9 –inch dbh); and medium/large Conifer (>25-inch dbh).

Additionally the expected time for the average small conifer stand to grow into a medium/large conifer stand will be reported.

Spatial and Temporal Bounding of Analysis Area

Spatial bounding will be limited to the treatment units within the project area. Silvicultural prescriptions and subsequent analysis are applied specifically to the stands designated as units. While trees can be affected by conditions that occur at the landscape level, for example, an insect epidemic, they are most significantly impacted by what occurs within tens of feet from their current location. Therefore, when bounding the silvicultural resource spatially, the actual stand was the unit size selected.

Temporal bounding for effects extends out to 30 years following inventory conditions. Treatments are projected in the years 2017 and 2018 with post treatment analysis ending in the year 2048. Stand development was modeled for a thirty year period. That is adequate time in which to display the differences on stand development between treating and not treating stands in the project area. This temporal bound also exceeds regional forester direction to incorporate treatments that are effective for at least 20 years.

Affected Environment

Background: The entire project area has had timber harvesting occurring for at least the past sixty years removing many, but not all of the largest overstory trees. The affected environment includes the effects of the past actions in the project area. In the 1950's the limited timber harvesting that took place generally was a light sanitation/salvage type cut that often removed a few trees per acre but these usually were some of the largest trees. During the 1960's there was an emphasis on regeneration harvesting (clearcutting) along with the fifties style partial cutting. District records indicate about 720 acres of clear-cuts and 800 acres of partial cuts. The clear-cuts were planted to Ponderosa pine of unknown seed source. In the 1970's another 1400 acres were treated implementing the Klamath partial removal prescription. An additional 100 acres were regeneration harvested as well. In the 1980's timber sales created both regeneration harvest units, about 400 acres, in the project area and involved more partial cutting on another 700 acres. There was a return to partial cutting in the 1990's and approximately 2200 acres received partial cutting with an improvement cut prescription. Hence, all stands in the current proposal have had some level of past harvesting take place in them at least once. Except for the regeneration cuts all the other past logging focused on removal of the larger trees in the stands with limited weeding and cleaning or pre-commercial thinning to remove undesirable sub-merchantable stems. The end results for the project area are 30-200 year old trees with the vast majority of the original overstory removed. Excluding conifer plantations, average tree ages in the areas recommended for treatment are in the 90-120 year range. Moderate ground fuel accumulations exist, and overstocked sapling to small saw timber sized stems are found throughout. Many of the roads were constructed as part of those projects. Numerous logging roads can be found throughout the project area.

The majority of the natural stands receiving treatment in the Lover's Canyon Project are located in the Canyon creek drainages. There is some treatment stands in both the Kelsey and Boulder creek drainages. Plantations to be treated are scattered across the entire project area. The elevation band for the project area is 2400 to 5500 feet. The composition of the vegetation is influenced in part by the elevation. At the upper elevations (generally above 5000 feet) forested stands are white fir dominated. Below 5000 feet these stands blend into the mixed conifer timber type. White fir becomes less dominant as elevation decreases. At the lower elevations (generally below 4500 feet) the forest type is mixed conifer. Aspect strongly influences stand composition with Douglas-fir and white fir dominating the north and east facing slopes. The pine species, incense cedar and Douglas-fir are more commonly found on the south and west facing aspects. In the absence of naturally occurring low intensity wildfires, white fir has significantly increased in magnitude and distribution. There have been no significant wildfires in the project area for the past 100 years, however, in 2014 the Happy Camp Complex fire burnt a large portion of the landscape near the project area and came into the project boundary on the northwest side. The Happy Camp Complex fire had very little impact on the project area itself, only spotting into a few small areas, however, this fire did have a landscape level impact on the Westside of the Klamath National Forest. The Deep Fire which occurred in September of 2017 was in the Project boundary but did not enter into any proposed units for this Project, and therefore is not within the silviculture analysis area.

The availability of water and nutrients affect overall stand vigor and growth. The project consists of productive soils (Forest Survey Site Class 1-4). Annual precipitation is 35 to 55 inches, with about 90% falling between October and May. At the higher elevations, the precipitation is predominantly snowfall. The availability of moisture is the most limiting factor for conifer survival and growth.

Stand density influences the amount of water and nutrients available to individual trees. High conifer stocking levels lead to competition for limited resources needed for growth and survival. Competition, in turn leads to reduced growth and vigor, increased susceptibility to insects and disease, and eventually mortality. Stand density affects stand health and the ability of trees to respond to disturbance mechanisms. High tree densities lead to increased competition for the limited resources needed to remain alive and growing. Weakened trees are more likely to succumb to the effects of disturbance mechanisms such as disease, insects and fire.

As seen in above, the landscape is lacking in pole and medium/large conifer stands, while nearly fifty percent of the stands are in the small conifer class. There is a need for action in order to accelerate the development of small conifer stands, moving them into the medium/large size classes to fall within the range of desired conditions.

All the proposed treatment stands in the project area are moderately to heavily stocked. Current stand densities are not sustainable over time as witnessed by ongoing mortality which is especially noticeable in the pine plantations and on the south and west slopes. Bark beetles are killing individuals and small groups of trees that have experienced the effects of overcrowding and disease. The stands, however, remain overstocked, susceptible to continuing insect attacks and increasing fuel accumulation. The effects from pervious partial cutting, heavily stocked stands, forest disease and pests, periods of drought, mortality, and a century of fire exclusion have put this area at substantial risk of a wildfire which would compromise its ability to meet desired future conditions as specified in the Klamath National Forest Land and Resource Management Plan (Forest Plan 1995). Hence, there is a need to take action and reduce infection, tree density, and fuel levels, both ground and ladder, in the project area. The role of the silviculturist in this project is to insure that the methods used to achieve objectives will maintain the productive capacity of the forested sites as defined in the KNF LRMP.

Disturbance Mechanisms: Stand health is also shaped by the types and amount of disturbance the stand has experienced over time. Fire, wind, insects and disease, as well as past management actions are all mechanisms which influence stand health.

Fire is an important disturbance mechanism in these stands. The project area is considered to be in a mixed severity fire regime, i.e., a fire would naturally result in a reduction of the basal area of the dominant vegetation by 20-70% (Agee 1993). In a mixed severity regime some areas would burn at a low intensity with minimal mortality; other areas would burn with moderate intensities; and still other areas would burn at high intensities, killing more than 75% of the dominant vegetation. The high intensity type fires will leave a mosaic of open ground with scattered pockets of timber.

The amount of area burned at the different intensity levels is influenced in part by the length of the fire free interval. Long periods without fire result in conditions more conducive to higher intensity fires as ground fuels accumulate, ladder fuels develop and stand densities increase. Decades of fire exclusion have dramatically altered the historical effects of low – and moderate – severity fires on forest structure and on the abundance and spatial arrangement of understory fuels historically created by low- and moderate- intensity fires (Taylor and Skinner 2003). Except for the northwest corner of the project area, no large fires have burned in the Lover's Canyon Project since records were kept on the forest dating back to the 1910's. The Kelsey fire, in 1987, was started by lightning on the lower half of the slope above the Kelsey creek trail, outside the current project area. Only 6 ½ % of the project area burned during this fire, and over 25 years have passed since that fire occurred. The Happy Camp Complex in 2014 burned into the project only affecting 5.02% of the project area, and 0.98% of planned treatment areas, all non-commercial thin plantations.

The long fire free interval for the majority of the project area as resulted in dense growth of poles and saplings (ladder fuels) and accumulations of ground fuels. Overall forests have increased in density and shifted in composition from more fire resistant to more fire sensitive species, reducing the structural diversity of the forests at both stand and landscape scales (Van Kat and Major 1978). Underburning after Cub and Canon timber sales (late '90s) was completed on much of the ground covered by those projects. Those treatments are now 10 years old. Fire as a disturbance process will be discussed in detail in the Fuels Resource Report.

Dwarf mistletoe produces swellings in the branches and open wounds on the boles of the host (Hawksworth 1977). These injuries to the tree provide opportunities for invasion by a number of pathogens and insects often resulting in the death of the tree. Dwarf mistletoe is an endemic disease, which is always present to some degree in conifer forests. The amount and intensity is now greater than it was one hundred years ago (personal communication B. Mathiasen 2005). Finally, the witches' brooms often associated with mistletoe infections are good receptors for sparks from wildfires and provide ladder fuels into the tree crowns when ignited. This condition enhances the probability of stand replacement due to fire.

Forest pests occur naturally in stands within the project area, most commonly fir engravers and western pine beetles. As stand densities increase and mistletoe infections increase an environment favorable to increased insect infestation is provided. Decreased availability of soil water, such as occurs in dense stands, and reduces a trees ability to pitch out attacking insects. Trees weakened by disease have similar difficulties. Increasing density and competition within stands in the project area will encourage increasing insect mortality in trees.

Fir engraver: the fir engraver (*Scolytus ventralis*) attacks most true fir species in the western United States. The attacks by this under the bark-burrowing beetle can result in patch kill around the bole, top kill, and tree mortality. Top kill and tree mortality are often associated with trees weakened by root disease, over stocking, drought, and heavy dwarf mistletoe infection (Keen 1952).

Western pine beetle: The western pine beetle (*Dendroctonus brevicomis*) is the most important insect enemy to ponderosa pine in California and Oregon. Normally this beetle breeds in windfalls, unhealthy trees, or in trees weakened by drought, stand stagnation, or fires and usually kills the tree (Keen 1952).

Current and Desired Stand Conditions: Analysis Indicator 1: Provide sustainable Resource Outputs:

below displays the current value of the measures for Analysis Indicator #1, to provide sustainable resource outputs.

Table 4. Existing Condition of Measures for Analysis Indicator #1

Measure	Natural Stands	Older Plantations
Basal Area (sq. ft.)	245	235
Stand Density Index	395	365
55% of Max. SDI	323	240

Analysis Indicator 2: Trend towards desired conditions for conifer stand structure:

The Canyon Ecosystem Analysis was prepared to provide a means by which the landscape can be understood as an ecological system, to use this knowledge to help shape the landscape patterns created through National Forest land management activities, and to provide recommendations consistent with the Forest Plan. The Canyon Ecosystem Analysis describes desired conditions for stand structural classes. below displays the desired range from the Canyon Ecosystem Analysis and displays the existing condition within the project area.

Table 5. Desired condition range and existing condition of the structural classes within the project area.

Structural Class	Desired Condition Range*	Existing Condition
Seedling/Sapling (0- to 5.9-inch dbh)	5 to 15%	6%
Poles (6- to 10.9-inch dbh)	10 to 20%	7%
Small Conifer (11- to 24.9-inch dbh)	15 to 35%	46%
Medium/Large Conifer (>25-inch dbh)	40 to 60%	38%
*As defined in the Canyon Ecosystem Analysis (page 48).		

Natural stands selected for treatment primarily fall into the small conifer structural class (11”-24.9” dbh). Also many existing plantations are planned for treatment and fall into a mix of structural classes from seedling/saplings to poles to small conifers. Currently the stands are densely stocked as evidenced by declining radial growth and interlocked crowns. Ingrowth of white fir has occurred on the north and east facing slopes as it is a species capable of establishing itself and growing under the canopy of other less shade tolerant conifers. This is particularly evident in those stands above 4000 feet. As evidenced by stumps in proposed treatment units, at the mid and lower elevations of the project, the original vegetative composition was dominated by ponderosa pine and Douglas-fir with sugar pine and incense cedar making up most of the remaining stocking. The south and west facing slopes while still pine dominated have very dense understories creating ladder fuels into the crowns of the overstory trees. The average tree diameters range from 9.5 inches to 17 inches. The stocking in treatment units is running between 1654 and 635 stems per acre while normal stocking would be in the 173 to 235 stems per acre range and averaging 15 to 19 inches in diameter for 100 year old stands (Dunning and Reineke 1933). The lack of natural fire has allowed the stands to reach these high levels of stocking. It has also allowed white fir to establish itself at lower elevations than would be found had normal fire return intervals remained uninterrupted.

Many of the stands are experiencing density related mortality. Many of those trees are now on the ground adding to the fire liability. Even though mortality continues the stocking levels are still abnormally high, dead fuel loading continues to increase and the live crowns of many understory trees are still near the ground. This scenario bodes well for large stand replacing wildfires when they occur. Dwarf mistletoe, particularly in Douglas-fir, incense cedar and ponderosa pine is also quite prevalent. Hardwoods are common in much of the project area but most are being overtopped by the conifers.

Natural Small Conifer Stands:

Current Condition: About 1000 acres of the project falls into this category. The stands range in elevation from 2400 feet to 5500 feet. They are densely stocked averaging 270 trees per acre (TPA) in the larger than 8” dbh size classes. Douglas-fir dominates the species composition. There are lesser amounts of ponderosa pine, white fire, sugar pine, and incense cedar as well. Mistletoe exists in all species but varies in intensity and distribution between the stands. The trees are dominated by stems in the 90-110 year age bracket. The Stand Density Index (SDI) for these stands currently averages 395. On the ground fuel loading is moderate. Pockets of young conifers are found throughout. There has been varying amounts of timber harvest documented since the 1950’s, usually targeting the larger diameter classes.

Desired Condition: The objective of the vegetative manipulation within these stands is to create areas that are structurally and species diverse, maintain or accelerate growth into the larger diameter classes (> 25” dbh) with canopy cover at 40-60% depending on aspect and slope position. Douglas-fir or ponderosa pine depending on aspect would be the dominant species with lesser amounts of sugar pine and incense cedar. This condition would not be uniform across the landscape as variability is important. Patches of denser stands would still be intermixed with the more open nature of the upper slopes. There should be a presence of hardwoods. Diversity of size classes will be scattered over the landscape, but a majority of the stands will contain conifers in the medium to large size classes (>25” dbh) (Canyon Ecosystem Analysis 1994). There will be gaps where early successional vegetation is present. Desired basal area is in the range of 120-160 square feet post project and would increase to 230-310 square feet (70-80% of normal), based on site quality and aspect, when stands reach 150+ years of age. Denser stands would be intermixed with these on 10-20% of the landscape. This would allow for areas of higher stocking, higher levels of mortality, undisturbed debris and size differentiation (Forest Wide LSR Assessment 1999). While not in a Late Successional Reserve LRMP land allocation, treatment stands are identified as critical habitat KLE7 designated under the 2012 Final Revised Critical Habitat Rule for the Northern Spotted Owl. As such, the long term desired stand conditions will closely mimic those found in LSR's.

The stands would be thinned from below to an SDI of less than 220 followed by treatment of all existing and activity created fuels. See the Fuels Resource Report for more specific fuels treatment information. Scattered, larger, dominant Douglas-fir, ponderosa pine and sugar pine will be cultured throughout the stands by removing surrounding trees that are competing for sunlight, moisture and soil nutrients. Canopy cover would range from forty to sixty percent. The greater canopy cover is desired where it currently exists and is comprised of the larger, thriftier trees in order to: maintain higher fuel moistures in surface fuels, reduce understory brush establishment and growth, and reduce fuels treatment maintenance costs, intervals and intensities. The pine species and Douglas-fir would be favored. Individual trees that have had stressors removed or reduced will be more resistant and resilient to climate changes (Joyce et al. 2009).

The Plantations:

<u>Current Condition:</u> Approximately 1551 acres of the proposed project comprise this category. The stands range in elevation from 2400 feet to 5500 feet. They are densely stocked with an average of 190 tpa. There are two distinct age brackets in this category. There are those stands planted in the 1960's through the 1970's and those in the early 1980's to the mid 1990's. The average tree diameter in the older plantations is 15 inches with an SDI of 365. In the younger stands the average diameter is 6 inches. The stands are dominated by Ponderosa and Jeffrey pines with lesser amounts of the Douglas-fir and incense cedar. Inventory data taken in the fall of 2012 reflect this. Due to current stand densities western pine beetles have begun killing small (less than ¼ acre) groups of trees with increasing frequency over the last five years in the older stands. Some of the older plantations have also been experiencing significant top breakage, primarily due to offsite stock being planted. Fuel loading is light but at least moderate in the disease and insect mortality pockets and in areas of snap tops.

<u>Desired Condition:</u> The desired stand structure would be compositionally more diverse than the current stands but generally less dense and it too should approximate pre-wildfire suppression era conditions. Fewer trees, less fuel loading and more grasses and forbs in the understory would be preferred (USDA 2000). Stands dominated by Douglas-fir and white fir would be preferred above 5000 feet. While stands in the mid to lower reaches of the project area would be pine and Douglas-fir dominated. Larger conifers with live crowns 20-30 feet from the ground that occasionally touch one another are desired. The stands would endure fast moving, low intensity wild fires without significant mortality. Stand Density Index would remain below 230 to preclude inter-tree competition induced mortality. The incidence of disease would be low. Hardwoods would be encouraged.

The stands would be thinned from below, at variable spacing. Trees in the smaller size classes would most frequently be removed. Scattered, larger, dominant ponderosa pine, incense cedar, sugar pine or Douglas-fir found singly or in groups will generally be retained and in some instances cultured by removing trees that are competing for sunlight, moisture and soil nutrients. The large tree culturing will: increase its resistance to insect attack; retain for a longer period of time more of the trees live crown; in some instances increase the growth rate of the tree. This culturing will create small gaps in the canopy of the stand. Hardwoods where they exist will be retained and their growth encouraged by thinning around them. Portions of the stands have a fair component of conifers less than ten inches in diameter. Where no larger, nearby conifers (greater than ten inches in diameter) exist, these thickets would be precommercially thinned. In areas where there are healthy, vigorous trees nearby, these smaller stems would be removed. A variety of methods to treat the fuels generated including whole tree yarding, hand piling and pile burning or underburning. In stands where offsite stock was planted retaining naturally regenerated conifers will be chosen for retention and wider spacing incorporated to retain those trees that have the potential to achieve the desired sizes for late successional old growth stands.

<u>2017 Winter Storm Damage</u>: The winter of 2017 resulted in storm damage throughout the project area. Heavy precipitation caused multiple new active landslide features to develop which affected both roads and proposed treatment units within the project area. Nine new active features, mapped by the Forest Geologist, totaled about 15 acres. Three units with 15% retention prescriptions lost approximately 3.3 additional acres of land scheduled to be treated. The remaining affected units with 25% retention prescriptions will incorporate active features into the retention area. Storm damage was determined to be minimum and was not enough to affect the analysis indicators.

Recommendations were made to avoid the risk of further initiating any new landslide activity in relation to these unstable areas. No trees will be removed from new active features. Project design features that were developed for reducing landslide risk will also apply to the new active features including equipment avoidance.

Environmental Consequences

For a full description of the alternatives refer to the Scoping Outcome Summary or Chapter 2 of the EA for the Lover's Canyon Project.

Alternative 1

As stand densities increase, the effects of inter-tree competition will intensify. Density related mortality will have the greatest effect on the smaller trees in the lower canopy classes but will also affect larger trees that are in a weakened condition. Also white fir, regardless of crown position, is more likely to succumb particularly under droughty conditions. As fewer trees occupy the available growing space there will be a gradual increase in the average stand diameter. As trees continue to compete for resources they will remain susceptible to the diseases and insects that are present. The mistletoe infection will continue. As time passes infection intensity will increase and heavily infected trees will succumb. Due to current insect conditions the older pine plantations will be the hardest hit in the next ten years. Fuel levels will continue to increase in all areas both as standing dead and ground accumulation. and Table 7 display the analysis indicators for the No Action Alternative. The two primary stand groupings are compared.

Table 6. Analysis Indicator #1: Provide sustainable resource outputs.

Measure	Natural Stands		Older Plantations	
	Existing Condition	30 Years	Existing Condition	30 Years
Basal Area (sq. ft.)	245	282	235	239
Stand Density Index	395	403	365	331
55% of Max. SDI	323	323	240	240

Table 7. Analysis Indicator #2: Trend towards desired conditions for conifer stand structure

Structural Class	Desired Condition Range*	Existing Condition, Landscape	Existing Condition, Within Treatment Units	Condition in 30 Years, Within Treatment Units
Seedling/Sapling (0- to 5.9-inch dbh)	5 to 15%	6%	7.23%	0.0%
Poles (6- to 10.9-inch dbh)	10 to 20%	7%	19.4%	7.2%
Small Conifer (11- to 24.9-inch dbh)	15 to 35%	46%	61.7%	77.6%
Medium/Large Conifer (>25-inch dbh)	40 to 60%	38%	11.7%	15.2%
*As defined in the Canyon Ecosystem Analysis (page 48).				
Years for small conifer to reach medium/Large conifer			60	

Direct Effects and Indirect Effects

Natural Small Conifer Stands: Currently 42% of the trees in this category are less than ten inches in diameter. Stands are already in a condition, greater than 55% of maximum SDI, that is not sustainable and competition induced mortality will continue to increase. Individual tree architecture will also be altered when subjected to such dense conditions; the live crown will be reduced, limbs will be shorter and smaller in diameter, and needles will not be retained for as many years as the trees drop their foliage sooner due to competition for light and moisture. Since the stands are mainly comprised of small diameter trees they will constitute most of the dead stems. Fuel loading will increase. Disease conditions will accelerate. Light to moderately infected trees will be experiencing fifteen to twenty percent loss in both height and diameter growth (Hawksworth 1996).

These stands will not be meeting desired future conditions for a number of analysis indicators. There will still be a significant small tree (ladder fuel) component. Fuel loading on the ground will continue unabated making the stands not fire resilient. Increased disease infection will lessen the lifespan of the larger more desirable stems and inhibit the growth of smaller stems.

With the no action alternative it can be expected for the natural small conifer stands to take about 60 years to reach the medium/large conifer size class. This 60 years assumes an absence of disturbance in the landscape, although, as mentioned above, no action leads to a landscape more susceptible to large scale disturbance from fire, insect, and disease.

Older Plantations: At present, more than 7 percent of the trees are less than 10 inches in diameter for stands in this category. Even with previous thinning the stands are at densities (365 SDI) that are well past 55% of max SDI (240) where competition induced mortality will occur.

On sites dominated by pine trees this overstocked condition puts the stands at additional risk from western pine beetle attack as the stands are significantly above SDI levels of imminent beetle induced mortality and getting worse each passing year (Oliver 1995). There has been some insect mortality pockets occurring over the past several years. Reaching desired future condition will be delayed at best for many of these stands and may not ever occur in others. As above the trees architecture will be affected living in such heavily stocked conditions; crown reduction, reduced branch size, and lack of needle retention.

Cumulative Effects

The health and resiliency of these stands is dependent on the condition of the stands as well as the conditions found in the surrounding forest. Dense overstocked stands with high mortality are at a high risk of stand replacing fire. Regular silvicultural and fuels treatments can reduce the overall fire liability across a landscape (Graham and McCaffrey 2003).

To address the concerns of stand health, cumulative effects will be evaluated only within the boundary of the project area. Insect and disease vectors can move into the project area from adjacent stands, without treatment, catastrophic losses could occur. Untreated stands are expected to remain susceptible to insect infestations. Pre-commercial thinning projects within the project area will not occur to cumulatively detract from the forest health and create stands that are further from the historical conditions than the current conditions.

Many of the stands in this project area have been experiencing density and disease related mortality for more than twenty years. The snags created are a result of periodic drought conditions, insect attacks and disease. This trend is expected to continue in the absence of treatment, as is evidenced through FVS modeling.

Alternative 2

This report focuses on the results of proposed silvicultural treatments. The proposed action is described for each vegetative group, followed by a discussion of the differences between alternatives.

and displays the analysis indicators and measures for Alternative 2. The two primary stand groupings are compared.

Table 8. Analysis Indicator #1: Provide Sustainable Resource Outputs for Alternative 2

Measure	**Natural Stands**		**Older Plantations**	
	Existing Condition	30 Years	Existing Condition	30 Years
Basal Area (sq. ft.)	245	258	235	149
Stand Density Index	395	324	365	196
55% of Max. SDI	323	323	240	240

Table 9. Analysis Indicator #2: Trend towards desired conditions for conifer stand structure for Alternative 2

Structural Class	Desired Condition Range*	Existing Condition, Landscape	Existing Condition, Within Treatment Units	30 Years, Within Treatment Units
Seedling/Sapling (0- to 5.9-inch dbh)	5 to 15%	6%	7.23%	0%**
Poles (6- to 10.9-inch dbh)	10 to 20%	7%	19.4%	0%**
Small Conifer (11- to 24.9-inch dbh)	15 to 35%	46%	61.7%	84.8%
Medium/Large Conifer (>25-inch dbh)	40 to 60%	38%	11.7%	15.2%
	*As defined in the Canyon Ecosystem Analysis (page 48). ** Modeling results indicate Modeling results indicate that seedling, sapling, and pole size stands will mature into small conifers stands within the 30 year time frame, leaving zero percent of the treatment unit stands in this structural class. This structural class is not in deficit in portions of the project area outside of treatment units. Trees of the Seedling/Sapling and Pole sizes do exist in the larger structural classes, but in lesser amounts, so as not to warrant that size classification. Areas heavily thinned will, with time, be reinvaded by sprouting conifer and hardwood seedlings.			
Years for small conifer to reach medium/Large conifer	50 Years			

Direct Effects

Natural Small Conifer Stands: The proposed treatment for all stands in this category emphasize reduction of present stocking levels to enhance development of the residual mid-mature and younger stems and increase the longevity of the mature stems. Included in this treatment is biomass reduction to improve current and future stand resiliency to wildfire. Thinning of both commercial and pre-commercial sized conifers at variable densities would occur.

In the thinned areas trees of varying size classes would be removed with the majority being the smallest trees in the stands. Hardwoods would be retained. Where they exist, Douglas-fir and the pines would be favored for retention in all stands. Individual large trees would be cultured by removing most of the surrounding trees that are competing for moisture and sunlight. Approximately fifteen percent of the area in these stands will remain minimally treated to untreated. Spots containing groups of larger trees and other late seral attributes would be the type of places selected for retention.

After treatment the average tree diameter would be 10% larger than left untreated. This is further demonstrated by natural stands taking 10 years less than if left untreated to reach the desired condition of medium/large conifer size class. This is assumed in a landscape is free from large scale disturbance.

Older Plantations: The proposed treatment for stands in this category emphasizes reduction of present stocking levels to enhance development of mid-mature and younger residual stems and increase the longevity of the mature stems that may be present. Conifers that have seeded in naturally particularly in areas planted with offsite stock, would be retained to enhance species diversity and genetic compatibility. Included in this treatment is biomass reduction to improve current and future stand resiliency to wildfire. Thinning of both commercial and pre-commercial sized conifers at variable densities would occur.

A thinning would remove trees in several size classes but the majority of the stems to be cut would be in the smaller diameters. Most hardwoods would be retained and their growth enhanced by thinning more heavily around them. The stands would have the Douglas-fir favored for retention. White fire would be the least desirable species to retain, particularly below 5000 feet in elevation. Individual large trees would be cultured by removing most of the surrounding trees that are competing for moisture and sunlight. Approximately fifteen percent of the area in stands will be minimally treated to untreated. Spots containing some late seral attributes, such as large trees, large downed wood; or seeps, and springs would be the type of places selected for retention.

After treatment the average tree diameter would be five percent larger than if left untreated. As many as five snags per acre, greater than fifteen inches in diameter would be retained. There currently is a snag deficit in this group. Particularly because trees that are dying seldom large enough to meet the Klamath LRMP snag guidelines.

Indirect Effects

Reducing stand densities will lessen the amount of future mortality. It will also provide more large trees sooner.

Natural Small Conifer Stands: Based on the modeling predictions for the next thirty years there would be nearly 33 percent more trees greater than twenty six inches in diameter than if left untreated. In thirty years stands would just be reaching densities where inter-tree competition induced mortality would again be starting to occur. Retention of hardwoods in the existing stands would occur.

Older Plantations: Projections for thirty years from now indicate there will be 17 trees per acre greater than twenty six inches in diameter. Only one tree per acre larger than 26 inches currently exists. Reduced stocking densities would preclude inter-tree competition induced mortality for approximately the next thirty years. Loss of hardwoods from the existing stands would be reduced.

Cumulative Effects

The health and resiliency of these stands is dependent on the condition of the stands as well as the conditions found in the surrounding forest. Dense overstocked stands with high mortality are at a high risk of stand replacing fire. Regular silvicultural and fuels treatments can reduce the overall fire liability across a landscape (Graham and McCaffrey 2003).

To address the concerns of stand health, cumulative effects will be evaluated only within the boundary of the project area. Insect and disease vectors can move into the project area from adjacent stands, however proper treatment within the project area can prevent catastrophic losses. Once stands are thinned properly, they can be expected to remain resilient for about thirty years. Pre-commercial thinning projects within the project area over the past twenty years will cumulatively add to the forest health and create stands that are closer to the historical conditions than the current conditions.

Many of the stands in this project area have been experiencing density and disease related mortality for more than twenty years. The snags created are a result of periodic drought conditions, insect attacks and disease. This proposed treatment as well as the past treatments would help to reduce the ongoing mortality and associated buildup of fuels.

Alternative 3

As described in chapter 2 of the EA, Alternative 3 has the same footprint as Alternative 2, but a reduced intensity of treatment specifically in a subset of natural stands where treatment is proposed. The reduction in treatment intensity will be accomplished by modifying the percentage of each treatment unit left untreated. Alternative 2 calls for a 15% retention component in each stand treated, while Alternative 3 calls for a 25% retention component in 25 of the 32 natural stands being treated with timber harvest. Subset of units applies to 91% of the acreage in natural stand treatment identified in the proposed action and would result in about 63 less acres treated. Six units with a 25% retention component contain new active features from 2017 storm damage. Active features containing standing trees will be incorporated into the increased retention areas. There are 694 acres of Natural Stands and 169 acres of Older Plantations being treated. When combined they total 863 acres of commercial treatment.

Therefore the direct and indirect effects on the older plantation vegetative group are expected to be the same for Alt 3 as for Alt 2, and the direct and indirect effects on the Natural Stand vegetative group are expected to be about 9% (63/694 acres) less effective for Alt 3 as for Alt 2.

Alternative 3 is described for the natural stand vegetative group, followed by a discussion of the differences between alternatives.

Table 10 and Table 11 displays the analysis indicators and measures for Alternative 3. The two primary stand groupings are compared.

Table 10. Analysis Indicator #1: Provide Sustainable Resource Outputs for Alternative 3

Measure	Natural Stands		Older Plantations	
	Existing Condition	30 Years	Existing Condition	30 Years
Basal Area (sq. ft.)	245	281	235	149
Stand Density Index	395	356	365	196
55% of Max. SDI	323	323	240	240

Table 11. Analysis Indicator #2: Trend towards desired conditions for conifer stand structure for Alternative 3

Structural Class	Desired Condition Range*	Existing Condition, Landscape	Existing Condition, Within Treatment Units	30 Years, Within Treatment Units

Seedling/Sapling (0- to 5.9-inch dbh)	5 to 15%	6%	7.23%	0%**
Poles (6- to 10.9-inch dbh)	10 to 20%	7%	19.4%	0%**
Small Conifer (11- to 24.9-inch dbh)	15 to 35%	46%	61.7%	84.8%
Medium/Large Conifer (>25-inch dbh)	40 to 60%	38%	11.7%	15.2%
	**As defined in the Canyon Ecosystem Analysis (page 48).* ***Modeling results indicate that seedling, sapling, and pole size stands will mature into small conifers stands within the 30 year time frame, leaving zero percent of the treatment unit stands in this structural class. This structural class is not in deficit in portions of the project area outside of treatment units. Trees of the Seedling/Sapling and Pole sizes do exist in the larger structural classes, but in lesser amounts, so as not to warrant that classification. Areas heavily thinned will, with time, be reinvaded by newly sprouted conifer and hardwood seedlings.*			
Years for small conifer to reach medium/Large conifer	50 Years			

Direct Effects

Natural Small Conifer Stands: The direct effects for alternative 3 would be almost the same as the direct effects described above in alternative 2. Compared to alternative 2, alternative 3 would have an increase in edge effect on vegetative growth. The extent is difficult to quantify since the exact spatial location and size of the retention areas is unknown at this time and can have a great effect on the amount of edge created in a stand. This edge effect would cause increased competition for light and water resources for trees in the thinned areas of the stand where they exist next to untreated areas. These untreated areas while providing additional positive northern spotted owl habitat attributes at the stand level will have little measurable effects at the landscape level.

For the 63 acres of additional untreated areas, the direct effects would be similar to those described in alternative 1 to varying extents based on the size of the untreated “skip” left in the stand. Very small skips could show little or no direct effects as described in alternative 1 and would experience conditions similar to alternative 2. As the trees in the “skips” grow in size they will be more likely to experience competitive stresses and more likely to attract insect and disease vectors and experience effects similar to those described for alternative 1.

Older Plantations: Same as alternative 2.

Indirect Effects

Reducing stand densities will lessen the amount of future mortality. It will also provide more large trees sooner.

Natural Small Conifer Stands: Based on the modeling predictions for the next thirty years the number of individual trees greater than twenty six inches in diameter will increase by nearly one third than would exist in those same stands if left untreated. Stands would just be reaching densities where inter-tree competition induced mortality would again be starting to occur sooner than in alternative 2. Retention of hardwoods in the existing stands would occur.

Older Plantations: Same as alternative 2.

Cumulative Effects

The health and resiliency of these stands is dependent on the condition of the stands as well as the conditions found in the surrounding forest. Dense overstocked stands with high mortality are at a high risk of stand replacing fire. Regular silvicultural and fuels treatments can reduce the overall fire liability across a landscape (Graham and McCaffrey 2003).

To address the concerns of stand health, cumulative effects will be evaluated only within the boundary of the project area. Insect and disease vectors can move into the project area from adjacent stands, however proper treatment within the project area can prevent catastrophic losses. Once stands are thinned properly, they can be expected to remain resilient for about thirty years. Pre-commercial thinning projects within the project area over the past twenty years will cumulatively add to the forest health and create stands that are closer to the historical conditions than the current conditions.

Comparison of Alternatives

Many of the stands in this project area have been experiencing density and disease related mortality for more than twenty years. The snags created are a result of periodic drought conditions, insect attacks and disease. This proposed treatment as well as the past treatments would help to reduce the ongoing mortality and associated buildup of fuels.

Table 12. Comparison of effects to Silviculture Analysis Indicators and Measures by Alternative

Indicator # 1: Provide sustainable Resource Outputs						
Measures	**No Action Alternative**		**Alternative 2**		**Alternative 3**	
	Existing Conditions	**30 Yrs. No treatment**	**Post Treatment**	**30 Yrs. Post Treatment**	**Post Treatment**	**30 Yrs. Post Treatment**
Basal Area: Natural Stands	245	282	160	258	161	281
Basal Area: Plantations	235	239	100	149	100	149
Stand Density Index: Natural Stands	395	403	238	324	262	356
Stand Density Index: Plantations	365	331	149	196	149	196

55% of Max. SDI.: Natural Stands	323	323	323	323	323	323
55% of Max. SDI.: Plantations	240	240	240	240	240	240
Indicator #2: Trend towards Desired Conditions for Conifer Stand Structure						
Measures	**No Action Alternative**		**Alternative 2**		**Alternative 3**	
	Existing Conditions	**30 Yrs. No treatment**	**Post Treatment**	**30 Yrs. Post Treatment**	**Post Treatment**	**30 Yrs. Post Treatment**
Quadratic Mean Diameter	9.6	16.3	11.5	19	10.7	17.7
Structural Class	Existing Conditions	30 Yrs. No treatment	Post Treatment	30 Yrs. Post Treatment	Post Treatment	30 Yrs. Post Treatment
Seedling/Sapling (0- to 5.9-inch dbh)	7.23%	0.0%	7.23%	0%	7.23%	0%
Poles (6- to 10.9-inch dbh)	19.4%	7.2%	14.7%	0%	14.7%	0%
Small Conifer (11- to 24.9-inch dbh)	61.7%	77.6%	66.4%	84.8%	67.4%	84.8%
Medium/Large Conifer (>25-inch dbh)	11.7%	15.2%	11.7%	15.2%	10.7%	15.2%
Years for Small Conifer to Reach Medium Large Size Class	60 Years		50 Years		50 Years	

Alternative 2 and 3 both more successfully meet desired conditions than Alternative 1. Compared to alternative 2, alternative 3 would treat 63 less acres within natural stands. This accounts for 9% (63/694 acres) less treatment in natural stands, and 7% (63/863 acres)less silvicultural treatment overall. Alternative 3 would be 7% less effective at meeting the indicators described above. It would result in a 1.3 inch reduction in QMD in 30 years, a 23 square foot increase in basal area, and 32 tree increase in stand density index when compared to alternative 2. Most notably within thirty years the stand density index for alternative 3 is above the 55% of maximum, indicating an increased risk of insect and disease related mortality as the stand enters the zone of imminent mortality, while it remains at this threshold in alternative 2 in the thirty year time frame.

Compliance with law, regulation, policy, and the Forest Plan

All alternatives comply with law, regulation, policy, and the Forest Plan as noted in the Forest Plan Consistency Checklist, available on the project webpage: https://www.fs.usda.gov/project/?project=42352.

Literature Cited

Agee, James K. 1993. Fire Ecology of Pacific Northwest Forests. Covelo, CA: Island Press 493 p.

Dunning, D. and Reineke, L.H. 1933. Preliminary Yield Tables for Second-Growth Stands in the California Pine Region. Washington D.C. U.S. Department of Agriculture. Technical Bulletin 354. 23 p.

Graham, R.T. and McCaffrey, S. 2003. Influence of forest structure on wildfire behavior and the severity of its effects. U.S.D.A. Forest Service. Rocky Mountain Research Station; 23 p.

Hawksworth, F.G. 1977. The 6 Class Dwarf Mistletoe Rating System. General Technical Report RM-48. Fort Collins, CO: U.S. Department of Agriculture, Forest Service. Rocky Mountain Forest and Range Research Station. 7 p.

Hawksworth, F.G., and Wiens, D. 1996. Dwarf Mistletoes: Biology, Pathology, and Systematics. Agriculture Handbook 709. Washington D.C.: U.S. Dept. of Agriculture, Forest Service. 410 p.

Joyce, L., Blate, G., McNulty, S., Millar, C., Moser, S., Neilson, R., Peterson, D. 2009. Managing for Multiple Resources Under Climate Change: National Forests. Environmental Management (2009) 44:1022-1032.

Keen, F.P. 1952. Insect Enemies of Western Forests. Miscellaneous Publication 273. Washington D.C. U.S. Department of Agriculture. 280 p.

Keyes, C.R. and O'Hara, K.L. 2002. Quantifying stand targets for silvicultural prevention of crown fires. Forest Science 21: 83-87.

Oliver, W.W. 1995. Is Self-Thinning in Ponderosa Pine Ruled by Dendroctonus Bark Beetles? Pages 213-218 in Lane G. Eskew, comp. 1995. Forest Health Through Silviculture-Proceedings of the 1995 National Silviculture Workshop; 1995 May 8-11; Mescalero, New Mexico. Gen. Tech. Rpt. RM-GTR-267. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Range and Experiment Station. 246 p.

Reineke, L.H. 1933. Perfecting a stand-density index for even aged forests. U.S.D.A. Journal of Agricultural Research, Washington DC, Vol.46. No. 7, 1933; p. 627-638.

Taylor, A.H. and Skinner, C.N. 2003. Spatial patterns and controls on historical fire regimes and forest structure in the Klamath mountains. Ecological Applications, 13(3), 2003, pp. 704-719.

USDA Forest Service. 1994. Klamath National Forest, Canyon Ecosystem Analysis. Yreka, CA. U.S. Department of Agriculture, Forest Service, Klamath National Forest.

USDA Forest Service. 1995. Klamath National Forest, Land and Resource Management Plan. Yreka, CA: U.S. Department of Agriculture, Forest Service, Klamath National Forest.

USDA Forest Service. 1999. Forest Wide LSR Assessment. Yreka, CA, USDA Forest Service Klamath NF.

USDA Forest Service. 2000. Klamath National Forest, Lower Scott Ecosystem Analysis. Yreka, CA. U.S. Department of Agriculture, Forest Service, Klamath National Forest.

Van Kat, J.L. and Major, J. 1978. Vegetation changes in Sequoia National Park, California Journal of Biogeography 5:377 – 402.